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DETERMINING AGE OF ATLANTIC SHAD FROM THEIR SCALES

By JAMES P. CATING

FISHERY BULLETIN 85

UNITED STATES DEPARTMENT OF THE INTERIOR, Douglas McKay, *Secretary*
FISH AND WILDLIFE SERVICE, John L. Farley, *Director*

ABSTRACT

Determining the age of shad (*Alosa sapidissima*) from scales has been considered difficult by many workers, and recent investigators have attempted to ascertain only the number of times of spawning. Much of the difficulty in reading scales arises in locating the first three annuli because accessory rings, or false annuli, sometimes are found in this area of the scale, and the annuli are not always clearly defined.

A method of locating these annuli, using transverse-groove counts, is presented. After the positions of the first three annuli are known, the age of the fish can be determined by counting any additional annuli which usually are easy to see, and adding the number of spawning marks. Criteria for determining whether annuli have been obliterated by spawning marks and the number of times the fish has spawned when one spawning mark has eroded into another are also presented.

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DETERMINING AGE OF ATLANTIC SHAD FROM THEIR SCALES

By JAMES P. CATING, *Fishery Research Biologist*

Determining the age of fish is important in y study requiring knowledge of the age-class mposition of the population. An accurate read- of shad scales was needed in the investigation the shad fishery of the Atlantic coast, being ried on by the United States Fish and Wildlife vice to furnish information for fishery regula- ns to the Atlantic States Marine Fisheries mmission.

This paper presents criteria established for read- the age of shad (*Alosa sapidissima*) from their les, in the hope that it may be of aid to other estigators. It is possible that the criteria given e, with minor changes, may be applied to other peids having scale markings similar to the d's.

Fishery biologists have generally considered d scales difficult to read, although most of them ee that some scales, especially from fish 4 years younger, are easily read because the annuli are ar cut and proportionately spaced.

Leim's (1925) paper on the life history of the d (*Alosa sapidissima*) in Canadian streams cusses the work by European investigators on e and growth of *Alosa alosa* and *Clupea finta*— y similar to *Alosa sapidissima*—in which they umed the validity of the annuli as year marks. plotting the length of scale against the length the fish for a group of shad, Leim showed that growth in length of the scale is almost propor- nal to the growth in length of the shad. He k-calculated the lengths of a series of shad at h winter of their life, and the calculated lengths eed closely with length of fish as he had meas- d them at a given age. His total lengths tted against age gave a curve that rose rapidly the fourth year, and then gradually leveled off. establishing the relation of length of scale to gth of fish, he fulfilled one of the important re- rements for establishing the validity of annuli year marks on shad scales.

In his work on the fresh-water growth of shad, Hammer (1942) found that shad scales are constant in number and retain their identity throughout the life span of the fish. He did not attempt to age shad, but did show that back-calculated lengths determined for the fish at the time they left fresh water agreed with actual measured lengths of shad at that time.

Borodin (1925) presented a method of reading shad scales by counting the number of transverse grooves and dividing by 2 to get the age. Greeley (1937), however, has pointed out that this method gives erroneous results on Hudson River shad scales and his age determinations from easily read scales agreed closely with Leim's. Later workers, for instance Moss (1946), read only spawning marks on the shad scales and presented no data on the age of the fish studied.

These investigators did not establish criteria for separating the false from the true annuli on scales or for ascertaining the amount of absorption that takes place at the scale edge during the spawning migration of older fish.

I wish to acknowledge the assistance of members of the staff at the Beaufort Laboratory of the Fish and Wildlife Service who helped with this study through their constructive criticism and advice during the period of its development. These are C. E. Atkinson, G. B. Talbot, R. A. Fredin, and John H. Finucane who worked with me during the earlier part of the study and assisted in reading scales.

DESCRIPTION OF A SCALE

Figure 1 illustrates a scale from a Hudson River female shad that was 11 years old, 22½ inches long, and weighed 6½ pounds when taken. The anterior, sculptured portion of the scale comprises about three-fourths of the scale surface, while the posterior area (exposed portion of scale) consists of the remaining one-fourth of

FIGURE 1.—A scale from a female shad measuring 22½ inches and weighing 6½ pounds. There are five annuli and spawning marks, and the fish was spawning for the sixth time, which makes it 11 years old. The Roman nume I through V represent the annuli, and VI through X the spawning marks. The Arabic numerals indicate the lowing: 1, annuli, or winter rings; 2, false annuli, or accessory rings; 3, fresh-water zone; 4, spawning marks striae; 6, transverse grooves; and 7, the baseline.

the surface area. The anterior portion has seven types of visible markings that are indicated by Arabic numerals on figure 1, as follows:

1. *Annuli, or winter rings.*—These are the lines seen on the surface of the scale following the contour of the periphery through both the anterior and posterior portions.[1] The annuli are usually most clearly seen in the lateral fields of the anterior portion near the baseline. On some scales they show very clearly on a diagonal line running from the center of the baseline to the shoul of the scale.

2. *False annuli.*—These are also called access rings and are similar in appearance to true ann On easily read scales they do not show up as cle as do the annuli, and are not usually found cling into the posterior portion of the s studied. These marks make age determina from shad scales difficult. Notice the less-emp sized false annuli between the true ones on scale shown in figure 2.

3. *Fresh-water zone.*—This is an important f annulus found on all shad scales and is laid d

[1] For optical reasons, the posterior areas of the annuli cannot be seen in this photograph. They may, however, be seen during microscopic reading of the scale by changing direction of the lighting.

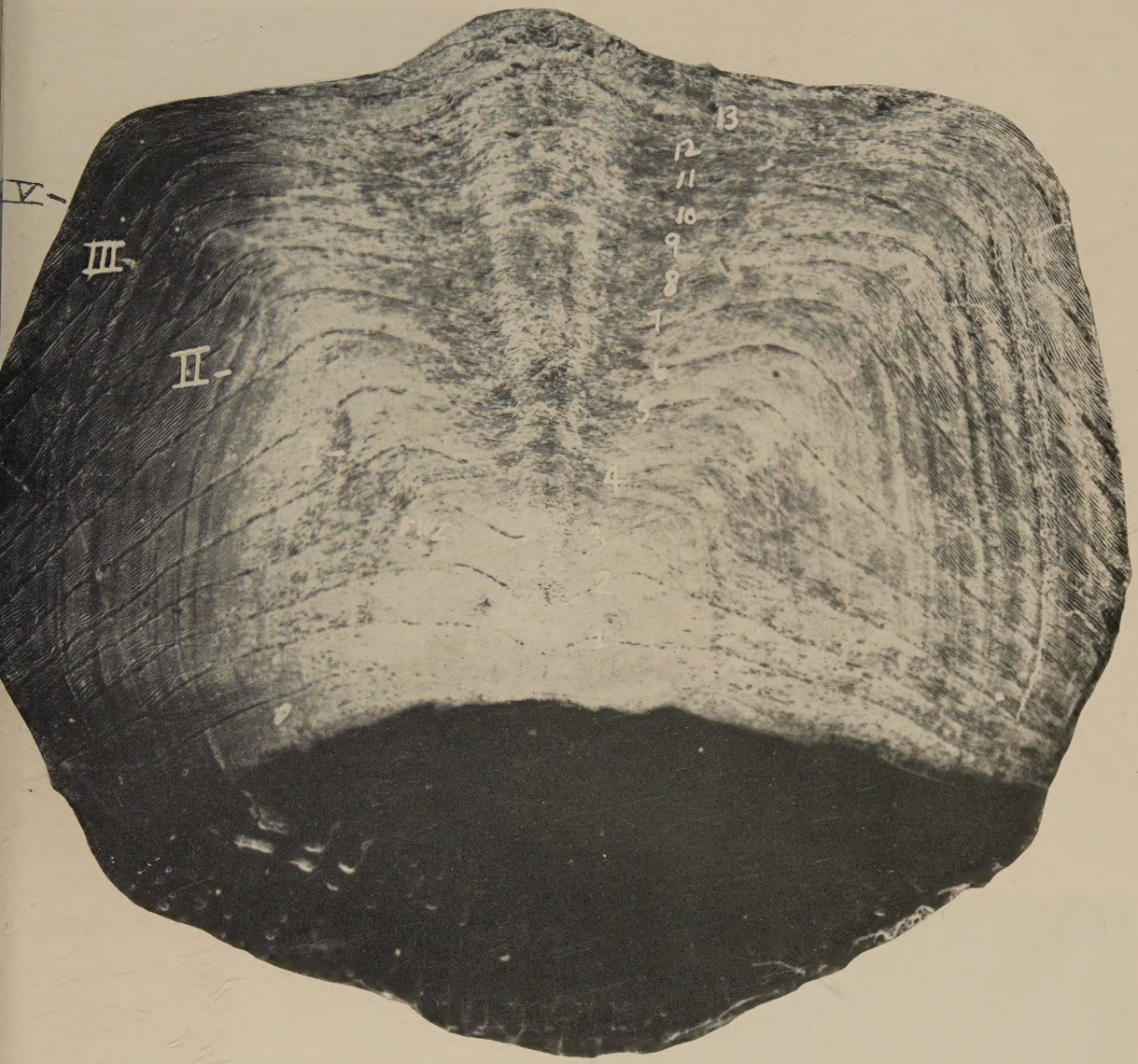


FIGURE 2.—Scale from a 4-year-old male shad measuring 16.2 inches and weighing 2 pounds 8 ounces.

en young shad pass from fresh to salt water at end of the first summer. Some workers apently have called this the first winter annulus, Hammer (1942) has shown that this line ns at the time of transition from fresh water he parent river to salt water in the ocean when shad are from 3 to 5 months old. Figure 3 irrates the scale of a young Hudson River shad mated to be 4 or 5 months of age and nearly ly to leave fresh water for salt water. If this l had lived longer the scale, as seen now, would e formed the fresh-water zone of the larger e.

4. *Spawning marks.*—These marks are scarlike rings extending around the anterior portion of the scale much as do the annuli, but unlike the annuli they extend only a short distance into the posterior portion of the scale. These marks are caused by absorption, or erosion, of the scale during the spawning migration into fresh water where little or no food is eaten by the adult shad. Figure 4 shows the condition of the edge of a scale from a shad just entering the Hudson River on the spawning migration. Notice the smooth margin. Figure 5 illustrates the irregular margin of a scale taken from a shad well up the river on the spawn-

ing ground. Figure 6 clearly illustrates a spawning mark (S. M.) formed a year previous to capture.

5. *Striae.*—These markings are fine ridges in the surface layer covering the anterior portion of the scale. They are very close together and run laterally across the scale in contour with the transverse grooves: figure 7 shows them clearly.

6. *Transverse grooves.*—These are distinct grooves in the surface of the anterior, sculptured portion, crossing it laterally on the same general contour as the striae, but spaced farther apart. Some of the grooves are continuous lines running from one edge of the scale to the other; others extend in from both sides without meeting in the center of the anterior field. Some of the groov start as a single line at the edge of the scale an then branch to form two lines.

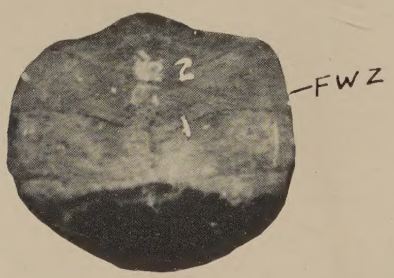


FIGURE 3.—Scale from a juvenile shad, probably 4 or 5 months old, caught while still in the river. There are only two transverse grooves. Had this shad lived longer the scale would have formed the fresh-water zone of the larger scale.

FIGURE 4.—Enlarged view of margin of the scale from a shad just entering the Hudson River on its spawning migration.[2]

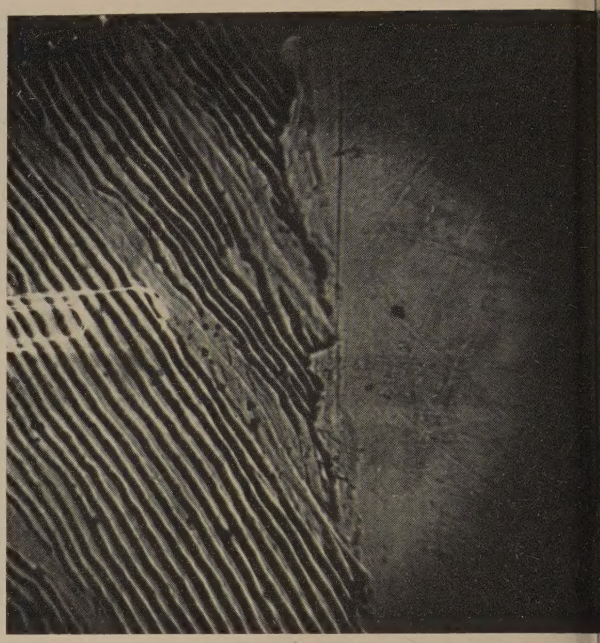


FIGURE 5.—Enlarged view of scale from a shad taken the spawning ground after a period in fresh water.[2]

7. *Baseline.*—In this paper the baseline is co sidered to be the first transverse groove on or ju anterior to the demarcation line between the a terior and posterior fields of the scale (also see in fig. 8).

PREPARING AND READING SCALES

The scales used in this study were collected du ing the spring of 1950, from Hudson River sha for use in age, growth, and mortality studie Many of the scales taken could not be used, eith because they were regenerate scales (fig. 9), or b cause they were asymmetrical and could not read. Four hundred nonregenerate and symme rical scales were chosen at random from the colle tion. Twenty scales, 2 each from 10 fish, were im pressed on individual 3″ x 5″ plastic sheets usin pressure and heat. Some scales were mounted glycerine jelly and polyvinyl alcohol on gla slides to compare their readability with scale im pressions on plastic. As far as we could dete mine, the one method is as good as the other, b since plastic impressions are easier to handle an less bulky to file, this method was used.

[2] Photographs from an unpublished manuscript of Louella Cable.

E 6.—Scale from a 19-inch female shad weighing 4 pounds. The single spawning mark (S. M.) is very clear on is particular scale. Note that the fourth transverse groove is branched. The Roman numerals indicate annuli nd spawning mark.

Recordak projector, designed for microfilm ng, and a binocular microscope of low power tried as sources of magnification. The Re-ak projector was found to be satisfactory for cting and reading the easily read scales, but e difficulties occurred, it was found that the oscope gave a better image of the scale mark-especially of the spawning marks. Most of mpressions were read by the latter method. llustrations used in this paper are negatives from the image on the ground-glass screen e Recordak projector.

attempt was made to read 400 selected scales ne conventional method of counting annuli spawning marks. Agreement in both re-reading and between 2 independent readings by 2 persons was obtained on 164, or 41 percent of the scales. Agreement between independent readings by two persons on the other 236 scale samples was poor because of poorly defined annuli and numerous false annuli. Because of this high percentage of disagreement it was considered necessary to develop criteria to distinguish the true from the false annuli or otherwise indicate the true age of the fish.

CRITERIA FOR DETERMINING AGE

Counting transverse grooves

Only those 164 scales that were clearly marked and on which consistent agreement had been

FIGURE 7.—Scale from a small male shad. Note that there are 10 transverse grooves to the edge of the scale indicated by Arabic numerals. The second annulus is just within the periphery of the scale, and was form during the winter just previous to this migration into fresh water where the fish was caught.

reached were used in the attempt to develop criteria for age analysis. Borodin's (1925) method of age determination by transverse grooves was tried. However, he gave no clear definition of what constitutes a complete or incomplete transverse groove; since none that we could devise appeared to give the desired results, this method was discarded.

While trying Borodin's method on the clearly marked scales, we noticed that the number of transverse grooves entering the fresh-water zone, and also the first, second, and third annuli, were almost constant from fish to fish. It was also observed that the spacing between transverse grooves, as with annuli, was proportional to growth. In other words, the distance between grooves becomes proportionally less as the fish grows older and its growth slows. Since the f mation of grooves seemed to be a function of a and growth, it appeared that their numbers mig be used as an index to the amount of growth taki place in any period and to locate the true ann on scales that were confused by false annuli.

To check these observations, counts were ma of the number of transverse grooves entering t fresh-water zone, first, second, and third ann on the 164 easily read scales. Counting began wi the first transverse grooves above the baseline, a grooves which branched were counted as one on All the transverse grooves entering the fresh-wat zone from one side were counted, including the that just touched the line enclosing the fres water zone. Those counted included incompl grooves (not joined in the middle of the scale)

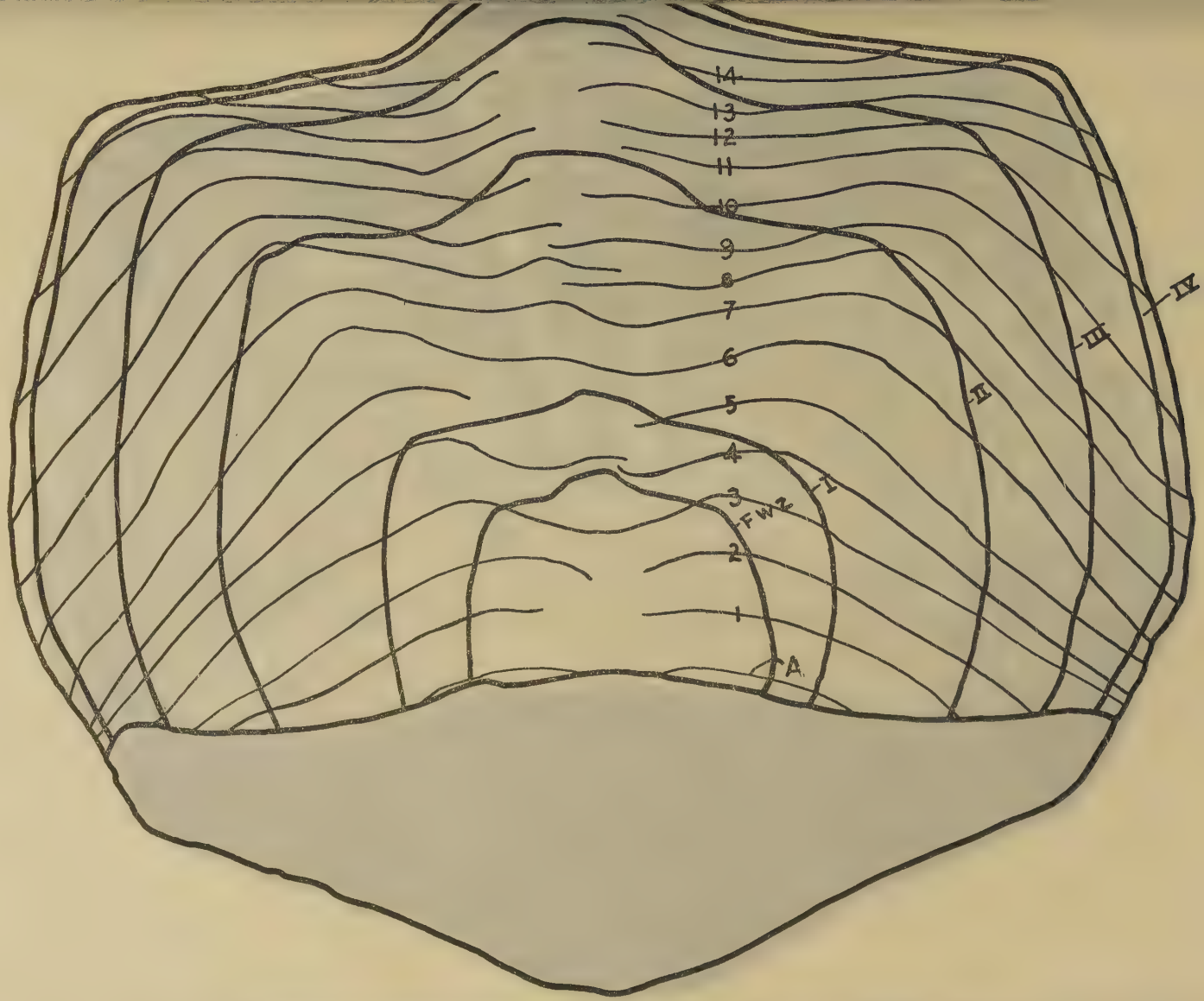


FIGURE 8–A.—Overlay to emphasize the major features of the shad scale in figure 8.

FIG. 1.—Cast of a deep pool in sandstone, showing the sandstone ripple-marks on the bottom.

FIGURE 8.—Scale from a female shad measuring 18.7 inches and weighing 4 pounds. Arabic numerals indicate transverse grooves, A the base line, Roman numerals the annuli, and VI/2 the fresh-water zone. Note the annulus just inside the periphery of the scale which was laid down during the winter just previous to spawning.

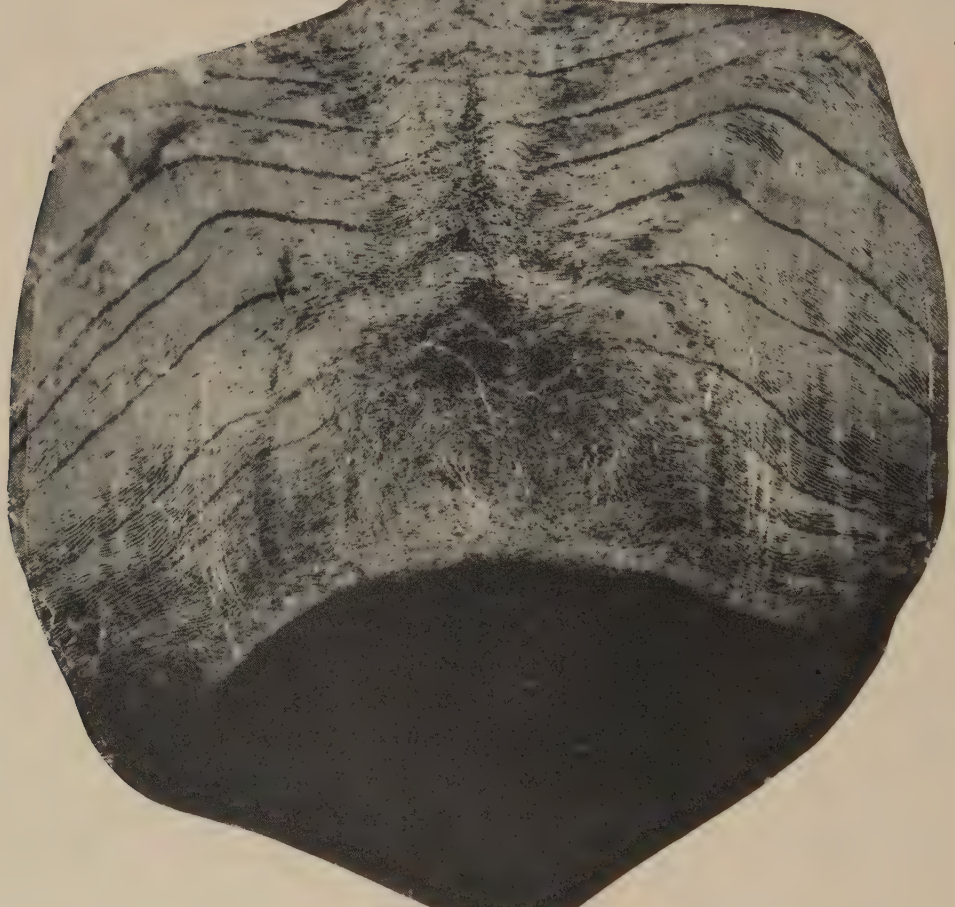


FIGURE 9.—Scale from a male shad that was probably 2 years old. This figure illustrates the appearance of a regenera scale.

well as complete grooves (extending unbroken from one edge to the other). Figure 8 illustrates this procedure of counting by numbering the transverse grooves 1, 2, 3, and so on, starting with the first transverse groove above the baseline. Since it is impossible to obtain photographs of shad scales with all details clearly shown, the diagrammatic overlay of figure 8 was prepared to help illustrate the items discussed. These are seen while actually reading the scales by changing the focus of the microscope to bring out each detail. The scale in this figure is from a 4-year-old female taken during its first spawning migration. On this scale there are 3 transverse grooves lying within the fresh-water zone, 5 within the first annulus, 10 within the second annulus, and 14 within the third annulus.

The transverse-groove counts made on the 1 scales are shown in table 1. The number of tran verse grooves lying within the fresh-water zone the scale ranges from 1 to 5, but is usually 2 or The number entering the area enclosed by the fi annulus ranges from 4 to 7, but is usually 5 or Within the second annulus, counts of 9 and transverse grooves predominate, but the range from 8 to 11. The number entering the area e closed by the third annulus is generally 13 or 1 with a range from 12 to 16. On a few fish whi had not spawned until they were 5 years old older, it was found that 16 to 18 transverse groov came into the area enclosed by the fourth annulu but, because of the confusion of lines caused by t scarred area in the central anterior portion of m scales, it was found to be of value to use groo

ts beyond the third annulus. This is not a dicap, however, because the annuli beyond the d are usually legible.

E 1.—*Frequency distributions of number of transverse oves entering area enclosed by fresh-water zone and t, second, and third annuli on scales of 164 shad taken the Hudson River, spring 1950*

ber of sverse oves	Distribution of 164 counts in—							
	Fresh-water zone		First annulus		Second annulus		Third annulus	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
	7	4.3						
	63	38.4						
	81	49.4						
	12	7.3	6	3.7				
	1	.6	85	51.8				
			69	42.1				
			4	2.4				
					16	9.8		
					58	35.4		
					78	47.5		
					12	7.3		
							8	4.9
							57	34.8
							79	48.2
							18	10.9
							2	1.2
Total	164	100.0	164	100.0	164	100.0	164	100.0

tancy of transverse-groove counts

o determine if the numbers of transverse oves were constant within the various annuli cales taken from various locations on the fish, cted samples of scales were mounted and read n five predetermined body locations on each 6 Hudson River shad brought to the laboraor special studies. The five locations chosen he left side of each shad were as follows: (1) midline of side just behind the gill opening; the midline of side under the dorsal fin; (3) midline of side near the tail; (4) just under dorsal fin; (5) just above the pelvic fins. ount of the number of transverse grooves en- ng the fresh-water zone and each of the first 3 uli was made from a scale from each of the 5 tions. This procedure was repeated for each he 26 shad. In most cases we found no varia- in transverse-groove counts between scales n the five locations on individual fish, and at they varied not more than ±1. The slight ation in scales from different locations l be a result of the difference in legibility arkings and of possible error in counting, but l cases the counts fell within the ranges shown ble 1.

It should be pointed out that the most symmetrical and legible, and therefore most easily read scales, are located on the midline of the side below the dorsal fin. Since even in this location many are regenerated scales (fig. 9), it was found necessary when sampling in the field to take about 20 scales in order to be sure of 2 good ones for mounting.

Spawning-mark criteria

The transverse grooves cannot be seen clearly on the part of the scale beyond the first spawning mark, due to scarring of the scale surface and the closeness of the spawning marks to each other. Since the spawning marks in most cases are clearly visible, there is no need for any index to them, for usually after a shad has spawned once, the spawning marks on the scales can be used with the annuli to determine the age of the fish. Only on shad that have spawned many times do the spawning marks become so crowded near the edge of the scale that they are hard to separate. This situation may be observed in figures 1 and 10 which show five spawning marks each. As many as nine spawning marks have been found on scales of individual fish taken in the 1950 Hudson River sample. On these scales it is usually possible to find traces of each spawning mark clearly visible just below the baseline in the posterior field of the scales where apparently not so much absorption takes place as in the anterior field.

Another problem encountered with spawning marks is that during the first spawning migration the previous year's scale growth around the periphery of the anterior portion is sometimes partially or wholly eliminated.

It is important when reading shad scales to examine the spawning marks to determine if an annulus has been eroded away. On scales where the annulus, laid down a year previous to the first spawning, has disappeared in the anterior portion of the scale due to erosion, a part of the annulus may be found near or just below the baseline of the scale inside the spawning mark, indicating that the absorption process does not affect the posterior portion of the scale to the same extent as the anterior portion. Figure 11 illustrates such a situation, and in reading this scale the part of the annulus remaining in the posterior region and the

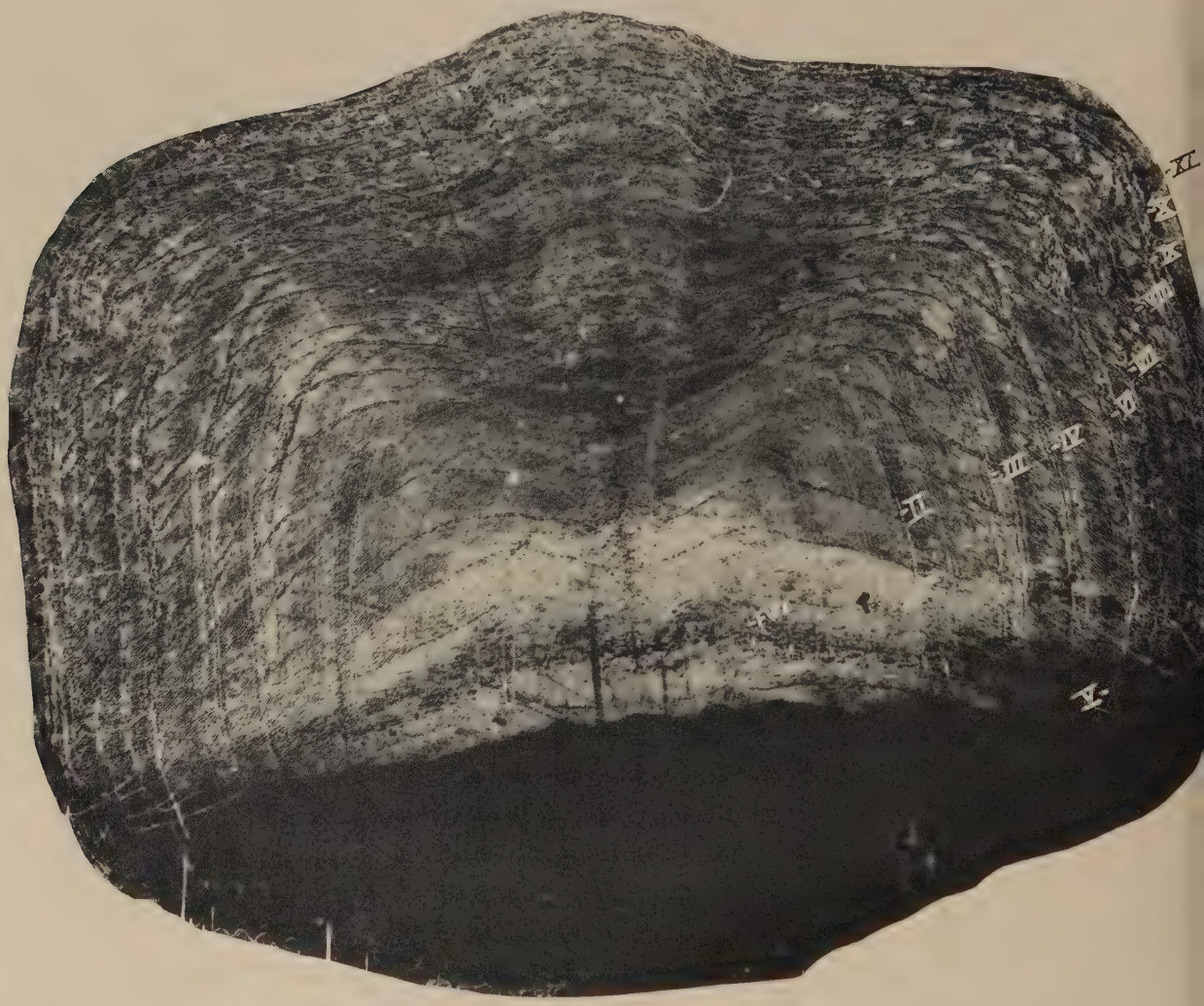
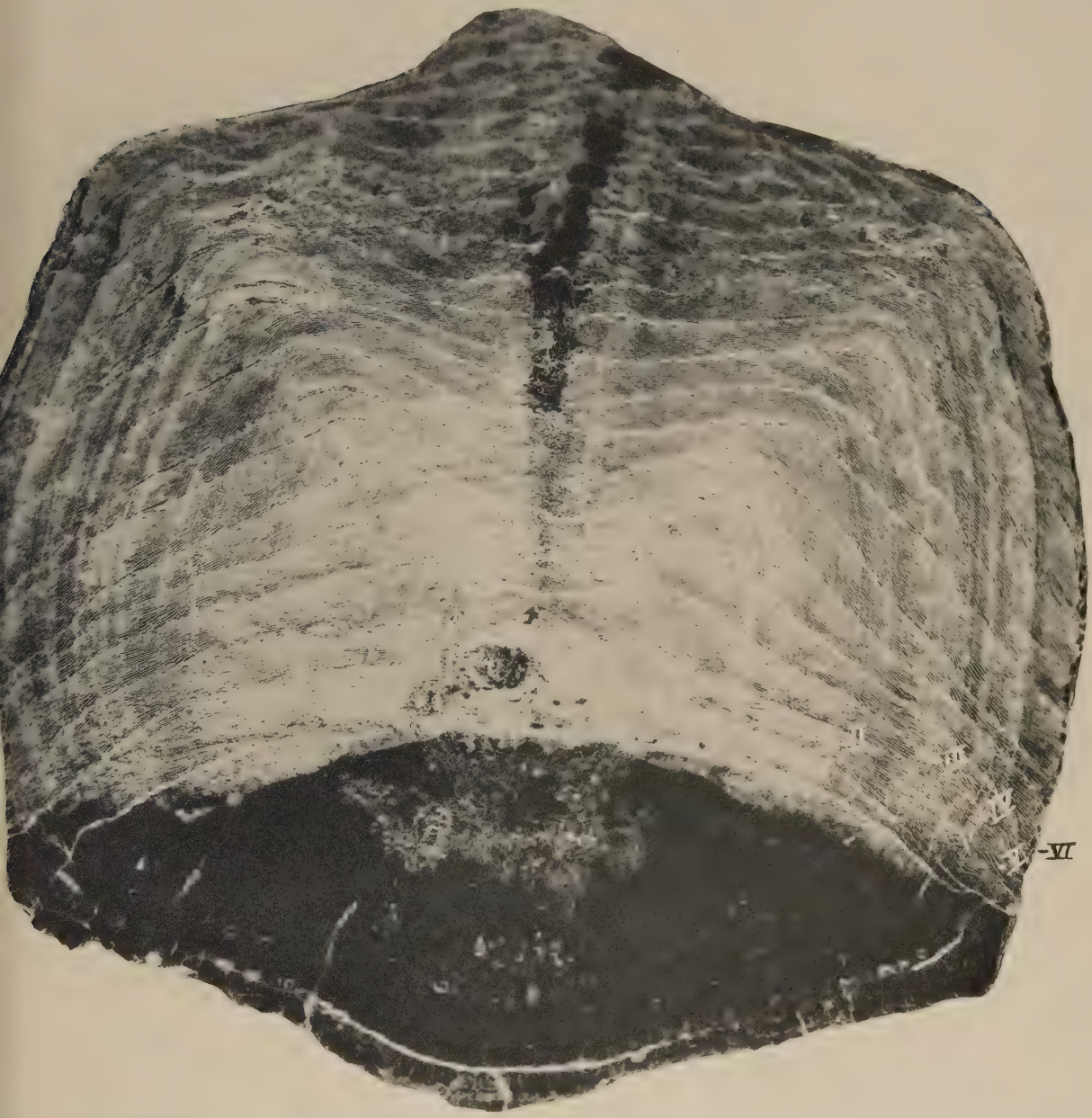


FIGURE 10.—Scale from an unusually large shad, a female, measuring 22.7 inches and weighing 7 pounds 9 oun Roman numerals VI through X represent spawning marks. Unfortunately, in this illustration the posterior tion of the scale is obscured so that the fifth annulus cannot be seen as separate from the first spawning mark below the baseline in the posterior portion.

spawning mark should each be counted as a year. We were fortunate in obtaining, through our tagging program in the Connecticut River during 1951, direct evidence of the amount of absorption occurring while the shad is in fresh water. Shown in figure 12 is a scale taken from a shad at the mouth of the Connecticut River during a tagging operation; it shows five distinct annuli and a space to the edge of the scale representing the growth during the sixth year. This shad was just entering the river on its migration to the spawning grounds as is evidenced by the smooth scale margin. A scale was taken from this same tagged fish when it was caught 51 days later off the coast of Massachusetts by a trawler; this fish apparen had spawned in the Connecticut River and t migrated out of the river and northward into Atlantic Ocean. The second scale is shown figure 11. One year's growth has almost b eroded away, leaving only pieces of the fifth nulus to be seen around the anterior periphery the scale. The fifth annulus can still be clea seen near the baseline just inside the ragged e of the scale.

The amount of erosion, or absorption, dur the first spawning migration appears to vary w the age at first spawning. For example, the s of a shad spawning for the first time at 6 y



URE 11.—Scale from the same female shad as scale shown in figure 12, but taken 51 days later. The fish was caught in the Atlantic Ocean off the coast of Massachusetts after leaving the river. Note the ragged periphery caused by absorption during the stay in fresh water, and the extent to which the edge was absorbed. The fifth annulus can be seen in only a few places. Compare this scale with the one shown in figure 12.

age usually shows absorption to or over the h annulus, as illustrated in figure 10; scales m shad that are spawning for the first time at ears of age are usually absorbed back to the rth annulus; scales from shad spawning for first time at 4 years are usually absorbed back ut half way toward the third annulus as shown figure 6; and a shad coming back to spawn at 3 years of age usually has scales absorbed one-fourth to one-half the distance to the second annulus. During any particular spawning run, the amount of absorption depends on the time the fish spends in fresh water. If the scales are from shad taken just before they enter fresh water, little or no absorption of the previous year's growth should be found.

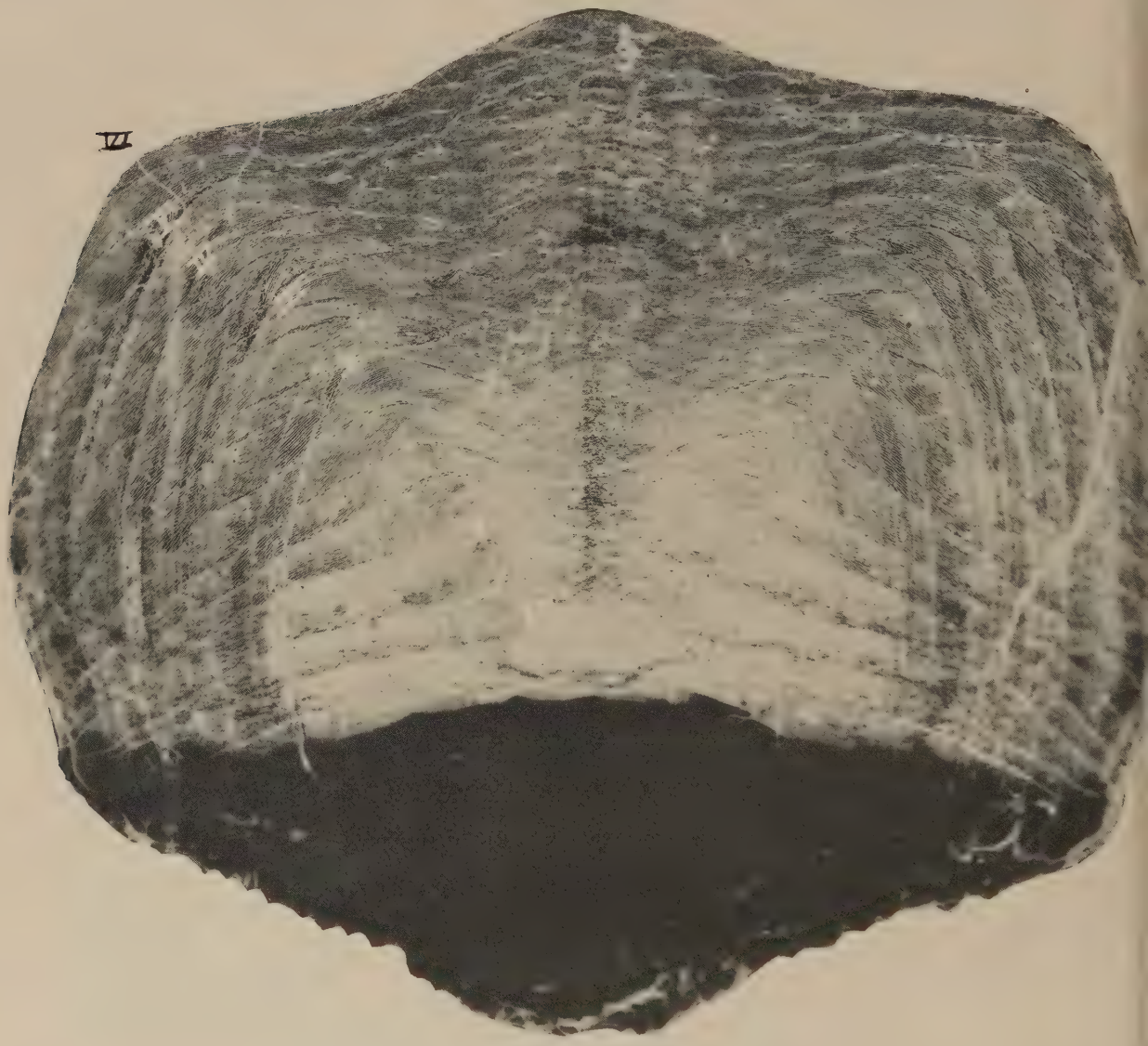


FIGURE 12.—Scale from a 6-year-old female shad measuring 19.1 inches. The fish was taken at the mouth of Connecticut River on its way to spawn for the first time.

APPLICATION OF CRITERIA

The criteria, as described, were applied to the scales on which poor agreement was reached, and little difficulty was experienced in determining the location of the first, second, and third annuli. Once the location of an annulus was determined by groove count, the annulus usually could be traced from the anterior sculptured area into the posterior area of the scale even though obscured and confused by false annuli. Usually the true annuli were represented by more heavily defined ridges in the posterior section than the false annuli.

The fourth, fifth, and sixth annuli were usua clearly visible and proportionately spaced scales of fish which had not previously spawn hence, by using transverse-groove counts to loc the first, second, and third annuli and then cou ing each annulus past the third one, it was possi to determine the age of shad which had not pr ously spawned.

Proficiency in interpreting the age of any s cies of fish from scales requires practice. Thi especially true when working with scales as d cult to read as the shad's; however, it is belie that by applying the criteria presented here, a

wishing to learn to read shad scales accurately
do so in a relatively short time. It is sug-
ted that anyone interested in applying these
teria should select several hundred shad scales,
l read them a number of times until the differ-
readings reach a desired level of agreement.

SUMMARY

From scales of the Atlantic shad (*Alosa sapi-
sima*) collected in the Hudson River in the
ring of 1950, 164 of the more easily read scales
re selected to serve as the basis for establishing
teria for determining the age of shad from their
les.

By counting the number of transverse grooves
tering the fresh-water zone, and the first, second,
d third annuli, it was found that the number of
h grooves is relatively constant from fish to fish.
e predominant number of transverse grooves
tering the fresh-water zone was 3; the first
nulus, 5; the second annulus, 10; and the third
nulus, 14. In a period of slow growth when two
nuli lay close together, the distance between the
nsverse grooves was found to be proportionately
s. Once the location of an annulus was deter-
ned by groove count, the annulus usually could
traced.

When a shad has previously spawned the spawn-
marks must be used with the annuli to deter-
ne the age of the fish. The spawning marks are
rlike rings extending around the anterior por-
n of the scale which are caused by erosion or
sorption of the scale when the shad enters fresh
ter to spawn. The amount of absorption that
urs depends on the age of the fish at the time it
kes its first spawning migration. Thus, it was
nd that scale absorption on a fish making its
st spawning migration when 3 years old usually
tends from one-fourth to one-half the distance
the second annulus. On a scale from a 6-year-
old shad spawning for the first time, however, the
absorption usually extends to or over the fifth
annulus. It is important, therefore, to examine
scales closely from fish apparently spawning for
the first time at 5 or 6 years of age to determine if
an annulus has been absorbed during the first
spawning migration. Usually, remnants of the
annulus previous to the first spawning can be seen
near the edge of the posterior region of the scale.
When there are several spawning marks on a scale,
and the marks have overlapped each other, traces
of each spawning mark are clearly seen just pos-
terior to the baseline.

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